

GROWTH OF ADHESIVE CUBIC PHASE BORON NITRIDE FILMS WITHOUT ARGON ION BOMBARDMENT

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Abstract

We show that adhesive cubic phase boron nitride (c-BN) films can be grown without the use of Ar ion bombardment. c-BN has several attractive properties such as extreme hardness, high thermal conductivity, and wide band gap (6eV). c-BN is also chemically inert to oxidation and ferrous metals. Previously, *in-situ* bombardment of massive ions (Ar^+ , Kr^+ , etc.) was considered to be necessary for the formation of c-BN films. Bombardment of massive ions has lead to c-BN films with poor adhesion to the substrates due to the accumulated stress. We found that while ion bombardment is still required for the formation of c-BN films, it can be achieved without involving massive ions. We have succeeded to growth adhesive c-BN films by two approaches: 1) plasma-assisted pulsed-laser deposition (PLD) in pure N_2 plasma, and 2) PLD in high vacuum ($\sim 10^{-5}$ mbar during growth).

INTRODUCTION

Cubic phase boron nitride (c-BN) films have attracted much attention due to its desirable properties such as extreme hardness comparable to diamond, high thermal conductivity, wide band gap (6eV) and chemically more inert than diamond to oxidation and ferrous metals, etc [1]. In the past decade, it was found that ion bombardment is necessary for growth of cubic phase boron nitride, especially with heavy ions, i.e., Ar or Kr ions [2, 3]. However, as an adverse effect of that, poor adhesion of cubic phase boron nitride is observed which hindered the actual application of c-BN films [4]. We have conducted a series of experiments in order to reduce the adverse effect of ion bombardment for the formation of adhesive c-BN films. It appears that adhesive c-BN films can be formed by pure N_2 plasma with reduced ionic flux at reduced deposition rate. Furthermore, energetic BN growth species generated by pulsed-laser deposition (PLD) could possibly sufficient for the growth of c-BN without the assistant of auxiliary ion bombardment. We have tested and verified these possibilities by using a PLD technique.

EXPERIMENTS

In the first approach, c-BN films were prepared at 600 °C by RF (13.56MHz) plasma-enhanced PLD [5-7]. A fourth harmonics generation of Nd:YAG laser ($\lambda = 266\text{nm}$) was used for the ablation of a hot-pressed h-BN target. The RF power was capacitively applied on a Si (100) substrate to generate a plasma in pure N_2 ambient at a pressure of 2×10^{-2} mbar. A negative dc bias voltage was induced by this plasma on the substrate for enhancing bombardment of positive ions during the deposition of BN films.

In the second approach, similar experimental setup was used for the growth of c-BN film in vacuum. RF plasma was not used in this case.

RESULTS AND DISCUSSION

In the first approach, all c-BN films were deposited within 4 h, with a constant substrate bias voltage of -500V. Different pulsed laser energies were applied in order to deposit BN films at different deposition rates. The BN films are characterized by Fourier transform infrared (FTIR) transmission spectroscopy. The IR absorption due to the entire BN film can be detected as shown in Fig. 1. Two absorption bands at 1390 and 780 cm^{-1} , represents the in-plane (B–N) and out-of-plane (B–N–B) stretching modes of the sp^2 -bonded BN phase. The c-BN band appeared at 1080 cm^{-1} [5, 8]. c-BN films with massive ion bombardment were easily peeled off. However, c-BN films synthesized in pure N_2 plasma is much more adhesive [5].

In the second approach, all c-BN films are deposited within 6h in vacuum. Different pulsed laser energies were applied in order to search for an optimum deposition rates for the formation of c-BN films. By using FTIR, the IR absorption due to the entire BN film can be detected for samples deposited at pulsed laser energy of 2.66mJ, 4mJ, 5mJ and 8mJ.

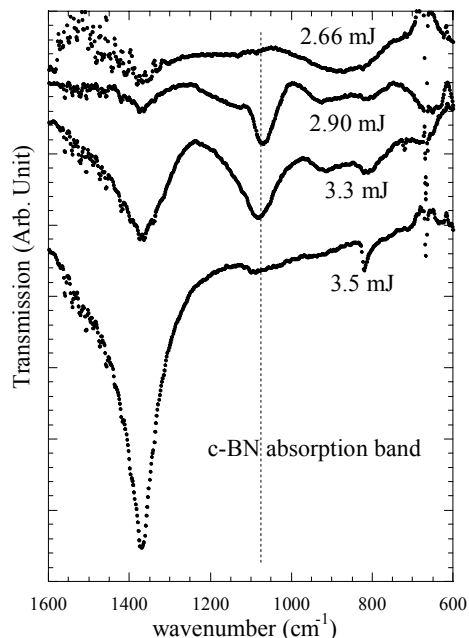


Fig. 1. FTIR spectra of c-BN films prepared at a substrate biasing of $-500V$ in pure N_2 plasma at various pulsed laser energies.

REFERENCES

1. Holleck, H., "Material Selection for Hard Coatings", J. Vac. Sci. Technol. A4, 2661 (1986).
2. Yoshida, T.: "vapor phase deposition of cubic boron nitride", Diamond Relat. Mater. 5, 501 (1996).
3. Kester, D. J.; and Messier, R.: "phase control of cubic boron nitride thin films", J. Appl. Phys. 72, 504 (1992).
4. Kester, D. J., et al., "growth and characterization of cubic boron-nitride thin-films", J. Vac. Sci. Technol. A. 12, 3074 (1994).
5. Yap, Y. K., et al, "Synthesis of adhesive c-BN films in pure nitrogen radio-frequency plasma", Diamond and Relat. Mater. 8, 382 (1999).
6. Yap, Y. K., et al., "Influence of negative dc bias voltage on structural transformation of carbon nitride at 600 °C," Appl. Phys. Lett. 73, 915 (1998).
7. Yap, Y. K., et al., "Hybridized boron-carbon nitride fibrous nanostructures on Ni substrates," Appl. Phys. Lett. 80, 2559 (2002).
8. Ichiki, T.; Momose, T.; and Yoshida, T.: "effects of the substrate bias on the formation of cubic boron nitride by inductively coupled plasma enhanced chemical vapor deposition", J. Appl. Phys. 75, 1330 (1994).